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TR 76-3

TECHNICAL REPORT NO. 76-3

SEMIANNUAL REPORT, PROJECT T/4703

SPECIAL DATA COLLECTION SYSTEMS

JULY 1975 – DECEMBER 1975

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TELEDYNE GEOTECH

TECHNICAL REPORT NO. 76-3

SEMI-ANNUAL REPORT, PROJECT T/4703
SPECIAL DATA COLLECTION SYSTEMS

July through December 1975

by

John R. Sherwin
and
George C. Kraus

Sponsored by

Advanced Research Projects Agency
ARPA Orders Nos. 2551 and 2897

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3401 Shiloh Road
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The work performed under Project T/4703, Special Data Collection Systems, during the period from 1 July through 31 December 1975 is described.

Five SDCS systems which had been deployed in early 1975 continued routine operations throughout the report period. Sites at Red Lake, Ontario, and Whitehorse, Yukon, are standard SDCS units; the site at Cumberland Plateau Observatory in Tennessee uses that station's SP array as its SP input. The Franklin, West Virginia, site uses a Model 36000 Borehole Seismometer System;

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20. Abstract (Continued)

the Houlton, Maine, site was a standard SDCS system until 11 December when a Model 36000 system was placed into operation. The five stations have routinely collected seismic data on a continuous basis throughout this period Data analysis tasks for the program are being done at the SDAC in Alexandria, Virginia. During the period 29 requests for event reports were received, or a total of 75 requests since March, and at the end of the period, 53 reports had been completed

During this period, five digital data acquisition systems ordered in May 1975 were received from the vendor. Equipment necessary to interface this system with the five operational SDCS units was designed and built. Four of these systems were installed in the field during November and December but various problems with vendor supplied equipment have delayed the start of routine digital data collection. At the end of the period, systems at CPO and HN-ME were operational.

Plans were formulated to begin a study of convection noise and its effect on the operation of the Model 36000 in the borehole.

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SEMI-ANNUAL REPORT, PROJECT T/4703
SPECIAL DATA COLLECTION SYSTEMS
July through December 1975

1. INTRODUCTION

The Special Data Collection System (SDCS) program, Project T/4703, is a continuation of work begun under the Long-Range Seismic Measurements (LRSM) program in 1960. This work is directed toward advancing the seismic detection, identification and location techniques necessary to detect and identify underground nuclear explosions.

This report describes the work performed under the SDCS program during this report period from July through December 1975 and is submitted in accordance with Sequence No. A004 of the Contract Data Requirements list as amended under Modification P00005, 2 January 1975. This research was supported by the Advanced Research Projects Agency of the Department of Defense and was monitored by AFTAC/VSC, Alexandria, Virginia 22314, under Contract No. F08606-74-C-0013.

2. FIELD OPERATIONS

2.1 GENERAL

The five Special Data Collection Systems (SDCS) assigned to field locations have been operated continually during the report period. There have been few major malfunctions and little data has been lost due to equipment failure. Each unit is operated and maintained by a single technician who is also responsible for vehicle and site maintenance. Digital recording equipment was installed at four locations during this report period. The fifth digital unit will be installed early in the next report period. The following paragraphs will be a discussion of the operational procedures and problems that apply to all sites.

2.1.1 Routine Operations

The original concept of SDCS operations was for short operational periods for special tests. The change in this concept to one of continuous recording required that a schedule of operations be established to make data reduction more efficient. Initially, the schedule followed a pattern established in the LRSM program of calibrations and record changes based on a Coordinated Universal Time (UTC) schedule with all units performing these functions at the same time. However, the UTC schedule was difficult for all sites to follow and still operate efficiently. Our present schedule is based on local time and has been satisfactory.

The present schedule calls for an eight hour work day during the week starting at 0800 local time and ending at 1630 local time. The weekend schedule is abbreviated and only calls for a site visit between 0800 and 1400 local time. With special permission an operator may be granted a one or two day weekend away from the site.

A routine work day starts at 0800 hours local time with routine operational checks to assure that data are being recorded on all channels from all instruments. At 1100 hours the digital tape is stopped, tape removed and transport cleaned and a new tape installed and restarted at 1115 hours. The start-of-run tests of the digital system are performed at 1120 hours. At 1200 hours, routine calibration of the seismic instrumentation is performed consisting of a 1.0 Hz sinusoidal calibration of the short-period system and a 0.04 Hz sinusoidal calibration of the long-period system. Both of these calibrations are performed at signal levels that will satisfy both analog FM and digital recording channels.

Each week, a frequency response calibration is performed on each system to assure that operational parameters are being maintained. Each month calibrations are performed to provide a closer control of operational parameters than that provided by the weekly calibrations. In addition to frequency response calibrations, seismometer damping checks and dummy load system noise tests are performed.

The analog FM tape system usually operates for several days before the tape is removed and sent to Garland for quality control checks and data playouts to assist the site operator. The tape is then sent to the SDAC for data processing. When digital recording systems are fully operational, it is expected that these analog tapes will be retained only as a backup for the digital recordings.

Procedures for handling the digital recordings have not yet been finalized. However, all tapes and logs will be sent from the fild to the SCAC for QC, data processing and storage.

Each operator calls the Garland office on Monday of each week to order needed supplies, discuss operational problems, review the analog tape QC record and to be alerted to future special operations. The operator is free to call for assistance at any time if the problem is of a serious nature and he has not been able to correct the malfunction after performing preliminary trouble-shooting.

2.1.2 Special Run Procedures

During the periods of activity at the Nevada Test Site (NTS) the operators follow established procedures to provide the best possible conditions for signal recording. The general procedure that is followed is outlined in the following paragraphs.

On the day prior to the event of interest, each operator is given anticipated signal amplitudes and advised to adjust attenuators and/or gain settings to provide a signal amplitude of approximately 1.0v p-p on the high gain analog

recording channels and 0.5v p-p into the digital channels. The operator also determines new sine wave calibration currents to satisfy the new settings for both SP and LP systems.

At one hour prior to the event, the SP and LP systems are calibrated at the routine calibration levels, attenuator and/or gain settings are adjusted and both systems are again calibrated using the sine wave calibration to satisfy the new settings. The calibrations are completed prior to the time the event is expected to occur. The operator observes the Helicorder trace for any sign of a signal for two hours and then proceeds to a telephone and waits for instructions from the Garland office. If the event has occurred, the site instrumentation is returned to routine operational settings and frequency response calibrations are performed on both systems; the tapes, digital and analog, are changed and sent off for processing. If there is a delay in the event specific instructions are given to the operators to insure operational status at the time of the event.

2.1.3 Problems Common to all Sites

The problems encountered in the field that have been common to all sites concern environmental difficulties and not instrument malfunctions. The moisture buildup in data line connectors, within the seismometer vault and within the seismometers has been the single most troublesome problem. The short-period data has not been affected but the long-period data channels exhibit spiking and the calibrations are unstable. The solution to the problem has been to perform periodic preventive maintenance consisting of drying all connectors and data line connections, drying the seismometer and replace damp fiberglass insulation that is used in the vault.

Access at all of the sites has been difficult at times. With only one man on site, the operators have been cautioned to take no unnecessary risks and to forego a site visit if the roads are unsafe.

2.1.4 Corrected Theoretical Response Data for CPO SP Instruments

The theoretical amplitude and phase response data for each SDCS site were reported in Technical Report TR 75-5, paragraph 3.4.4, and in Appendix I. During this reporting period, it was discovered that an additional low-pass filter (fc = 2.95 Hz, λ = 0.385) had not been included in the calculations for the CPO short-period instruments. Curves shown in figure 9 and the calculated data in Appendix I of TR 75-5 are therefore incorrect for the CPO. Figure 1 shows the corrected curves, and tabular data are shown in the Appendix to this report. This filter will be removed from the CPO SP system in February and theoretical data shown in TR 75-5 will then be correct.

2.2 FIELD LOCATIONS

Each field location is similar in the function of the instrumentation utilized and the data being recorded. The sites differ in the types of instrumentation employed and the environmental conditions under which operations are maintained. Figure 2 is a map showing the site locations for SDCS

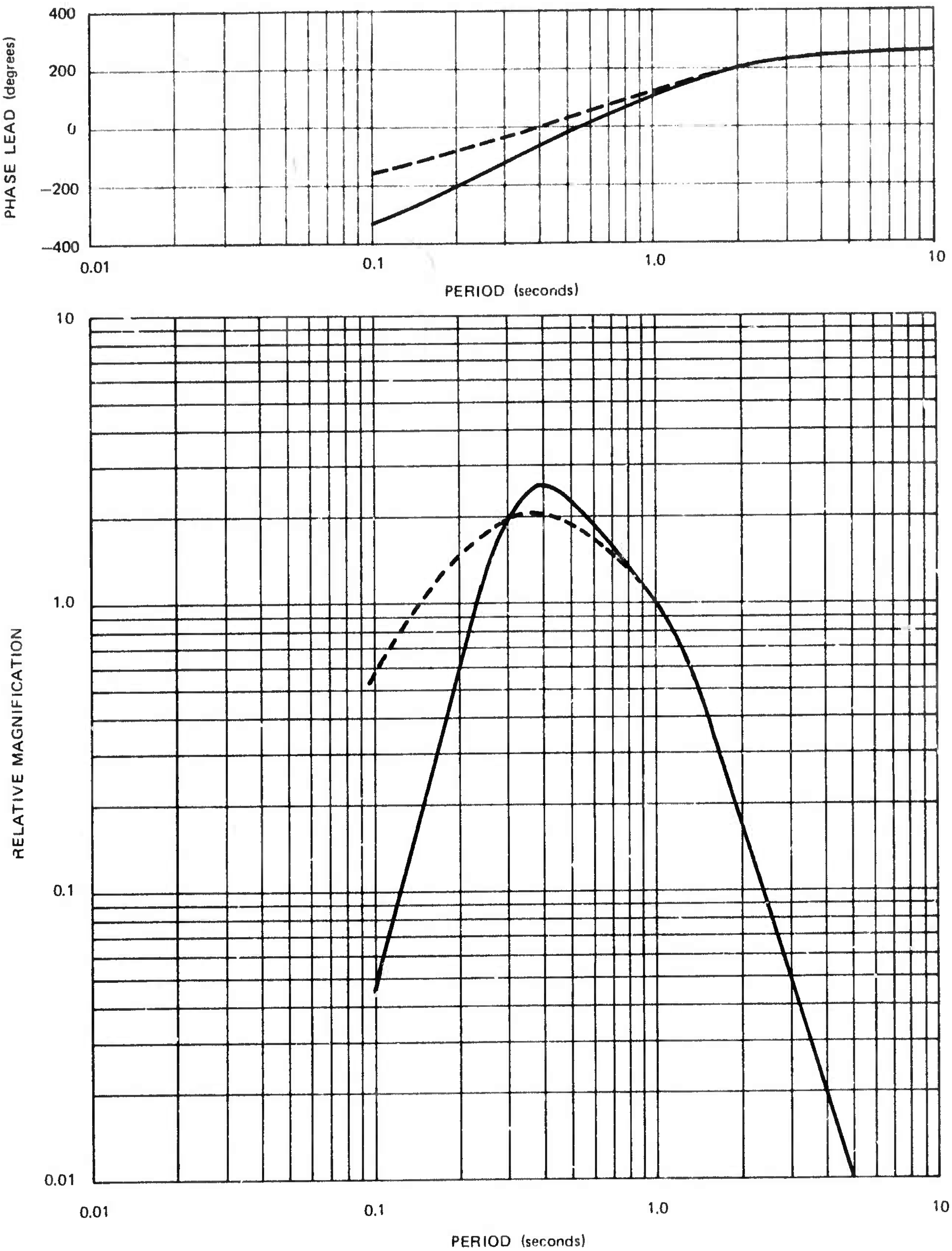

Figure 1. Corrected theoretical amplitudes and phase responses of the short-period seismographs at the Cumberland Plateau Observatory. Dashed lines show previously reported data.

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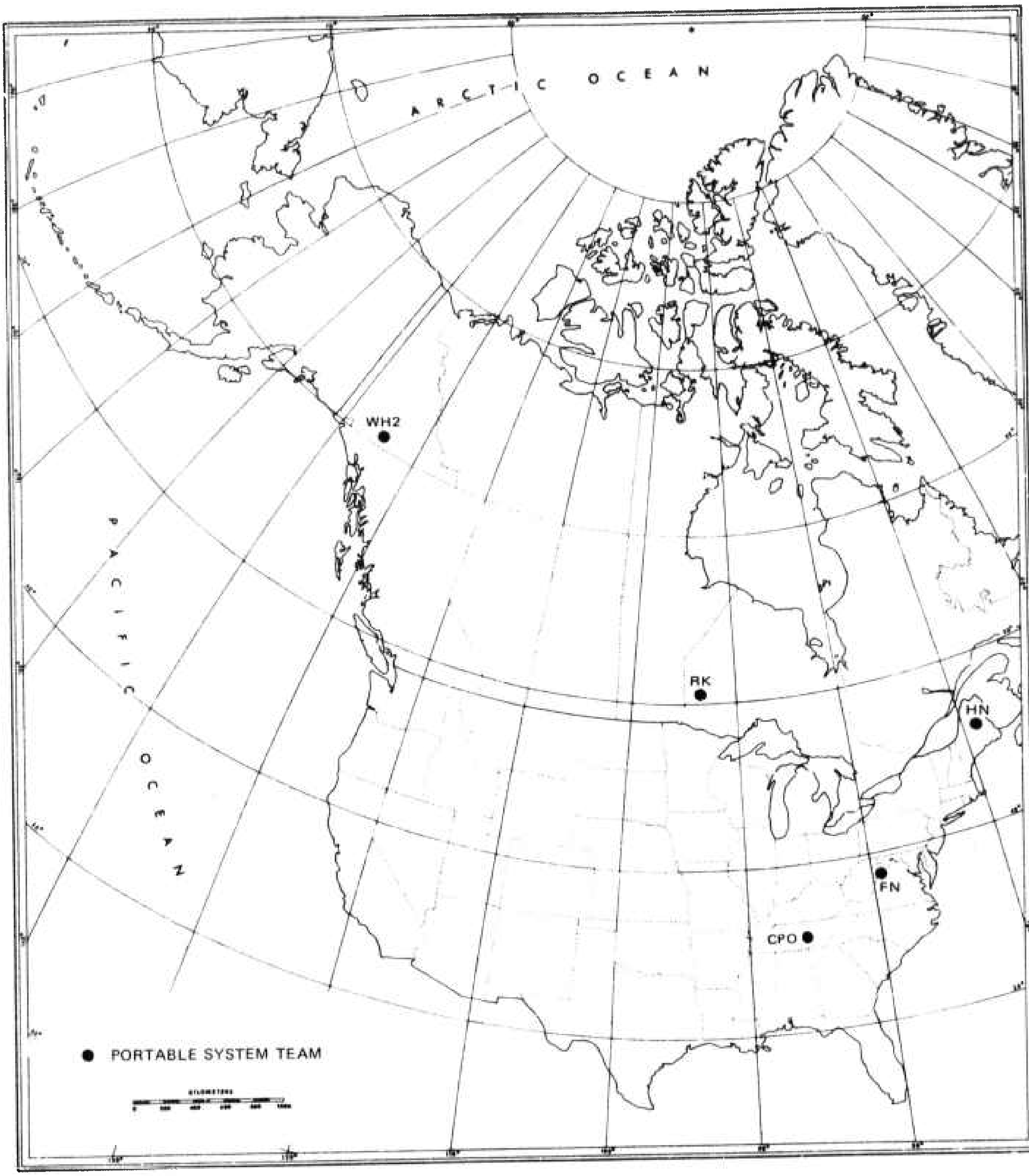

Figure 2. Site locations for SDCS operations during the period from January through July 1975

G 8241

operations during the period July through December 1975. The following paragraphs will summarize the activities at each site during this report period.

2.2.1 Franklin, West Virginia, (FN-WV), Team 56

At the beginning of the report period, the Model 36000 Borehole Seismometer (KS) was operating in a water-filled shallow borehole because the deep borehole casing was not sufficiently constrained at the instrument operating depth and the noise levels due to this condition were unsatisfactory. The data from the shallow borehole indicated the noise levels of the horizontal channels was twice as great as that of the vertical, but in any case the operating magnifications were three to five times greater than that at any other SDCS operating location. However, the noise levels did not remain constant but gradually increased and then dramatically decreased again following a heavy rain associated with a cold front passage. The noise level then began to increase again, indicating that the environment in the water-filled shallow borehole was at least partially responsible for the noise as seen on the long-period records.

In order to provide a change in the operating environment of the borehole seismometer, the annulus between the 9-5/8-inch surface casing and the 7-inch deep borehole casing was filled with cement poured in from the top of the well. It was hoped that this would constrain the 7-inch casing sufficiently to provide a more satisfactory operating environment for the Model 36000 Seismometer.

Although the pouring of the cement from the top of the annulus did not provide this positive control of completely filling the annulus between the casings as would pumping from the bottom, the relatively low-cost of pouring the cement from the surface was the deciding factor in taking these steps.

In December 1975, Model 36000 Borehole Seismometer, S/N 2, modified to include the most recent improvements in KS assembly techniques, was installed at a depth of 160 meters in the dry, deep borehole. At the end of the report period the data recorded had none of the noise characteristics recorded prior to the change in boreholes. An examination of the Model 36000 Borehole Seismometer, S/N 4, after its return to the Garland facility revealed no apparent electrical or mechanical malfunction which could explain the noise. This strongly suggests that the noise source was related to the operational environment in the water-filled, shallow borehole.

The orientation of the holelocks was not checked in either borehole as the orientation tool ordered by the Project Office was not received during this report period. The Digital Acquisition System, Model DDS-1103, was delivered on site in December 1975 but recording of digital data was not started due to instrumentation problems which had not been resolved at the end of December 1975.

Figures 3a and 3b show the FN-WV site location. Figure 3a shows the winch and mast assembly near the deep borehole during the original holelock orientation determination by Sperry-Sun in the Spring of 1975. Figure 3b shows the mast in the down position near the deep borehole. The water-filled shallow

Figure 3a. FN-WV

Figure 3b. FN-WV

Figure 3c. CPO

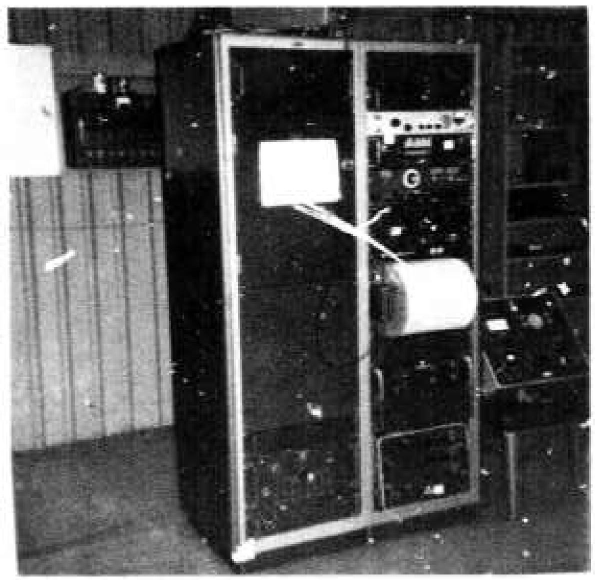

Figure 3d. CPO

Figure 3. FN-WV and CPO site pictures

G 8803

borehole is in the right background. The equipment shelter and pickup truck are shown in both photographs.

2.2.2 Cumberland Plateau Observatory (CPO), Team 57

The operation of the Cumberland Plateau Observatory (CPO) presented no unusual operational problems. The major problems have been in maintaining the 19-element short-period array data lines and moisture related problems in the long-period circuitry.

During September, USGS personnel installed equipment to telemeter four channels of short-period vertical data from SPZ 1, SPZ 4, SPZ 7, and SPZ 8 to Virginia Polytechnic Institute and State University in Blacksburg, Virginia. In October, USGS personnel were transferred and the SDCS operator assumed sole responsibility for operating and maintaining all seismic instrumentation. He also assists in maintaining the telemetry equipment.

The first of the Model DDS-1103 Digital Acquisition Systems was installed at CPO early in November. The installation was accomplished with little difficulty although an examination of the records showed some modification was required. These modifications were completed in December with no difficulty.

Figure 3c shows the central recording building at CPO and figure 3d shows some of the SDCS equipment in the station.

2.2.3 Houlton, Maine (HN-ME), Team 58

The plan to move the site to the original HN-ME location in order to utilize the 7-5/8 inch API cased borehole could not be accomplished as the litigation concerning the land title was not settled and no adequate site lease could be obtained. Therefore, a local driller was contracted to drill and case a borehole to meet the specifications required for Model 36000 Borehole Seismometer operations and yet keep the cost within the budget of the contract. The new borehole was completed at the new HN-ME site in late November 1975 after leasing arrangements were finalized allowing us access to the site location for 10 years, even if the land is sold. It was planned to have a cased borehole deep enough to allow operations at a depth of 50 meters (165 ft) but a fracture zone and/or solution cavaties were encountered at about 45 meters (147 ft) during drilling operations that resulted in a water flow of over 200 gallons per minute. The drilling continued to a depth of 52 meters (171 ft) and the water flow never diminished. It was decided to plug the hole above the source of water to eliminate any problems associated with the cementing of the casing and in the instrument operations. The lower part of the hole was filled with gravel. A cedar plug was run in the hole to a depth of 39 meters (127 ft) where a good contact in an impervious rock was obtained. The welded casing was run in, cemented and blown dry, leaving a working depth of 38 meters (125 ft) within the borehole.

The Model 36000 Borehole Seismometer was placed into operation on 11 December 1975 and immediately there was marked improvement in the LP data quality, as expected. The SP data quality did not show such a marked improvement as the microseismic noise noted on the records is due to the close proximity to the ocean and not to any local phenomena.

The Digital Data Acquisition, Model DDS-1103, was installed on 10 December and data from the surface instruments were recorded digitally until the installation and checkout of the borehole seismometer was complete. A quality control examination of the first Houlton digital records indicated a problem existed in the alternate memory portion of the unit. The manufacturer was examining the problem at the end of the report period.

Figure 4a shows the surface vault in the foreground with the recording hut and the team vehicle in the background. Figure 4b shows the recording shelter with the borehole drill rig in the background.

2.2.4 Red Lake, Ontario, Canada (RK-ON), Team 59

The log bunker at Red Lake had to be replaced due to the extensive rotting of the wood and the expected collapse of the earth backfill. A smaller, concrete block bunker was constructed and backfilled during this report period. Routine operations were maintained as much as possible during the retrofit and no extensive data loss was experienced. The amount of maintenance on the bunker instrumentation necessary to maintain operations has been reduced significantly since the installation of the new bunker.

The operation of the generators for on-site power has been reasonably reliable. In October there was a generator failure that could not be repaired on site, but that was the only significant failure.

The strike of the Canadian Postal Service during October, November, and December 1975 caused severe problems in maintaining current data shipments and in sending needed spare parts and operational supplies to the team.

Figure 4c shows the generator shelter in the foreground with the recording shelter, team vehicle and instrument bunker in the background. Figures 4d and 5a show the bunker entry and figure 5b shows the bunker interior with instrument vault open prior to resuming operations after bunker retrofit.

2.2.5 Whitehorse, Yukon, Canada (WH2YK), Team 60

The routine operations during this report period have been without unusual problems. As reported previously, WWV and WWVH radio time signals are not reliably received and the same problem exists with the reception of radio time signal broadcasts on other frequencies. The most satisfactory method of using radio time signals is to try the reception at various times during the day, even to returning to the site after routine operating hours.

The strike of the Canadian Postal Service caused the same problems at Whitehorse as it did at Red Lake. Data shipments out of, and shipments of operating supplies and spare parts into Whitehorse were delayed. The Model DDS-1103, Digital Acquisition System, was installed during December 1975 and data recording started on 19 December. Some difficulty was encountered during installation due to the unit being miswired by the manufacturer. This problem required telephone contact from the site to Kinemetrics to solve the problem. A quality control check of the first digital tape showed a high background caused by a radio frequencey signal and its harmonics from a

Figure 4a.   HN-ME

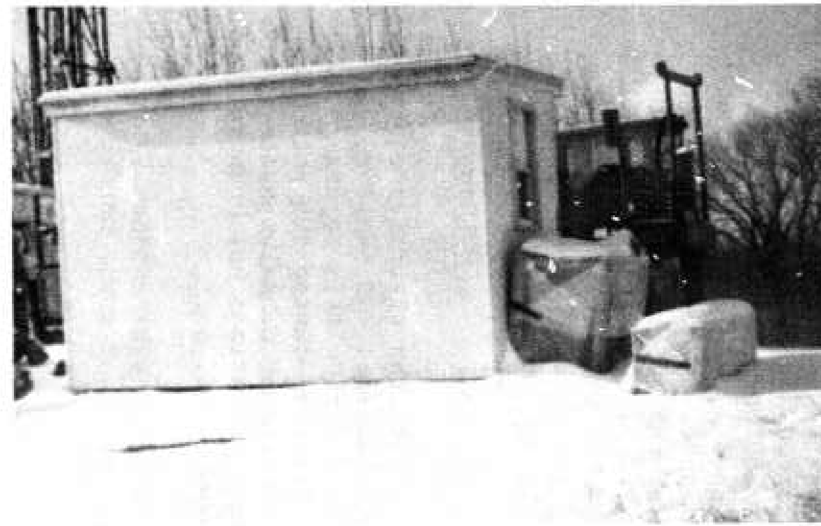

Figure 4b.   HN-ME

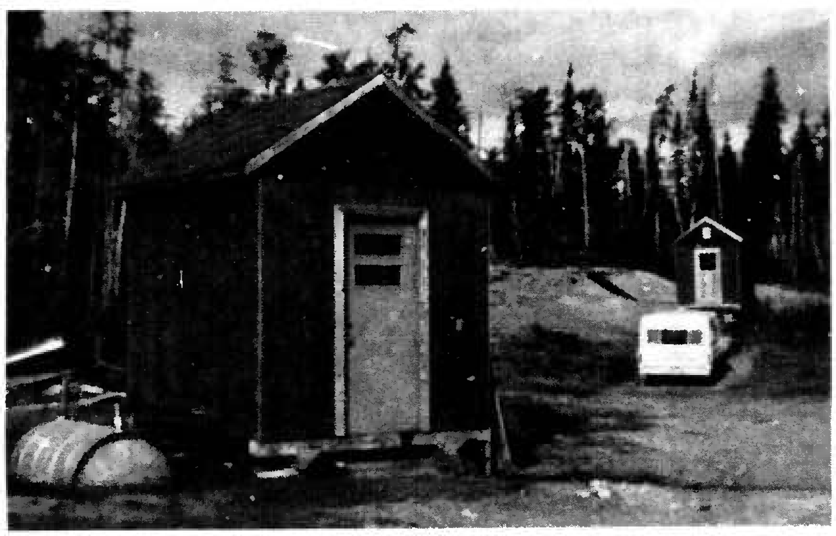

Figure 4c.   RK-ON

Figure 4d.   RK-ON

Figure 4.   HN-ME AND RK-ON

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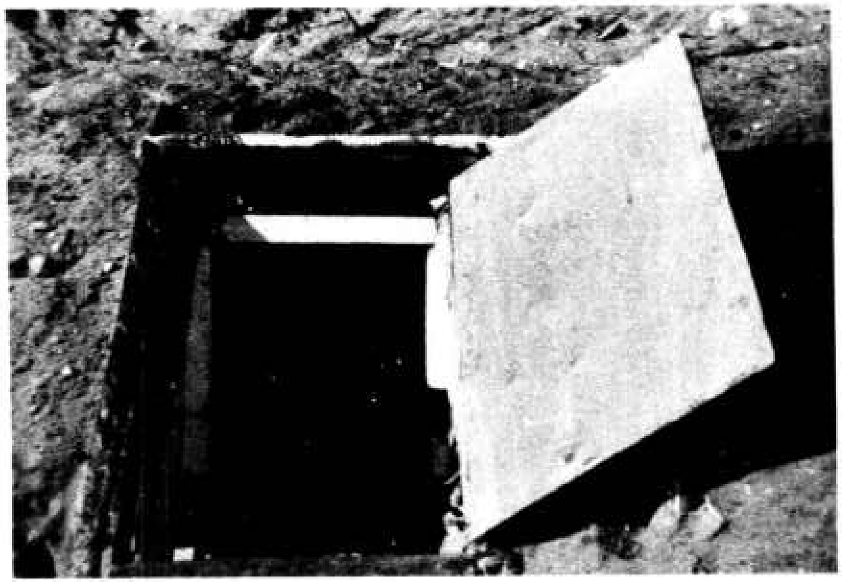

Figure 5a. RK-ON

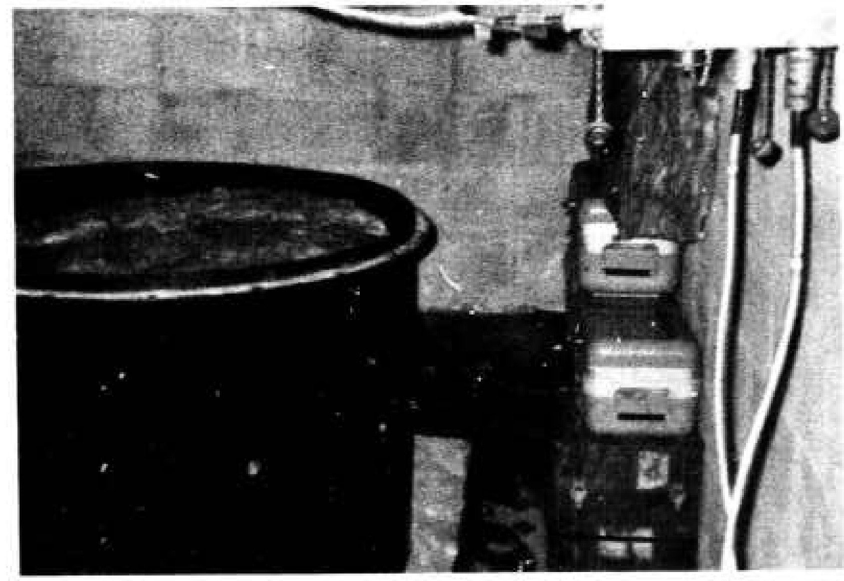

Figure 5b. RK-ON

Figure 5c. WH2YK

Figure 5d. WH2YK

Figure 5. RK-ON and WH2YK

G 8805

nearby radio transmitter. A filter was designed to eliminate, or at least to diminish the magnitude of the problem; however, this had not been accomplished at the end of the report period.

Figure 5c shows the recording shelter at WH2YK and figure 5d shows the top of the equipment bunker.

2.3 DIGITAL RECORDING SYSTEMS AT FIELD SITES

2.3.1 Installation of Systems

During this reporting period, considerable effort was placed on completing work on digital recording systems for the five SDCS teams (see Section 3 below). When work was completed, the systems were prepared for shipment and installation at the various sites. Table 1 shows the installation dates and system status at the end of the reporting period. The table shows that only two of the five systems could be considered completely operational as of 31 December.

Table 1. Installation data for digital recording systems

Site	Start Installation	Operational Date	Comment
FN-WV	16 Dec	-	Controller returned to vendor on 2 Jan 76 for repair of problems discovered during installation
CPO	4 Nov	5 Nov	Final modification to produce acceptable data on 19 Dec 75
HN-ME	4 Dec	12 Dec	First tape showed spike problem but subsequent tapes found to be acceptable
RK-ON	-	-	System returned to vendor on 21 Nov 75 to solve "extra byte" problem for all systems. Scheduled to be returned to Dallas in mid-January
WH2YK	16 Dec	19 Dec	No apparent problem in system operation but nearby broadcast transmitter causing noise on data channels

The system at WH2YK could be considered operational but the rf pickup from the nearby broadcast transmitter was a continuing problem. Analysis of the digital data and on-site tests indicated that the rf energy was being picked up on the system ground and was therefore bypassing the anti-alias filters on the input data lines. The result is a sinusoidal alias signal at a 30 to 40 count level (75 to 100 mV) within the data passband on all channels caused by "undersampling" the rf signal. If the station operator is

unable to reduce this pickup to acceptable levels, on-site assistance will be provided from the Garland office.

The systems for FN-WV and RK-ON will be installed when the vendor satisfactorily resolves the operating problem in the systems. It is estimated that all systems will be fully operational by the end of February.

2.3.2 System Response Changes for Digital Recordings

The anti-alias filters included in the Digital Recording Systems are necessary to prevent noise on digital recordings. Operation of these filters is discussed in paragraph 3.2.4 below. The filter corners are at a frequency higher than most data in the SP and LP bands, and therefore, little correction is necessary for normal seismogram presentations. For detailed studies, however, seismograph amplitude and phase responses shown in this report and in TR 75-5 should be corrected for digital recording using the appropriate data shown in the Appendix of this report.

3. DIGITAL RECORDING SYSTEMS

3.1 GENERAL

An order for five digital recording systems for the SDCS teams was placed with Kinemetrics, Inc., in late May 1975. During the reporting period, the work necessary to incorporate these systems into the SDCS units was completed. This included (a) design, prototype testing and documentation of the Interface Unit, P/N 42052; (b) assembly of the Interface Unit baskets, modules, and cables; (c) receipt and acceptance testing of the digital systems, and (e) installation work at four of the five SDCS sites. In addition, a brief on-site training program and new station operating procedures were developed.

Figure 6 is a block diagram and figure 7 is a photograph of the completed system. In the photographs, the Interface Unit and Blower Panel were built by Geotech and remaining units make up the Data Acquisition System, Model DDS-1103 furnished by Kinemetrics, Inc.

3.2 INTERFACE UNIT, P/N 42052

The Interface Unit, P/N 42052, is shown in figure 8 and provides signal conditioning for all inputs to the DDS-1103 which originate in the Portable Seismograph System, Model 19282A. In the following paragraphs, the function of the various modules is discussed.

3.2.1 Time Data Interface, P/N 41924

The time-of-day data recorded in the header of each digital tape record (days, hours, minutes, and seconds), is furnished by the SDCS timing system. The -2.2 to 0V logic level of the SDCS timer is not compatible with the 0 to +5V TTL logic in the DDS-1103 system. Logic level conversion for the 30 data bits is therefore accomplished in two 15-channel Time Date Interface Modules, P/N 41924. The level conversion circuitry is relatively simple and the module has no external controls.

3.2.2 Control, P/N 41926

The Control Module, P/N 41926, provides level conversion for the 20 pulse per second signal from the station timer to the DDS-1103. This signal sets the sample rate for the SP data; the 1 sps LP sample rate is derived from this signal by circuitry in the DDS-1103. One of the most important functions of the control module is to synchronize the start of every 12-second long digital record with real time; and because time is recorded only to an accuracy of one second in the header, it was necessary to provide "on-the-second" starting to prevent timing errors of up to 950 msec. Circuitry in this module provides for automatic resynchronization in the event that the header time does not coincide with the start of the record.

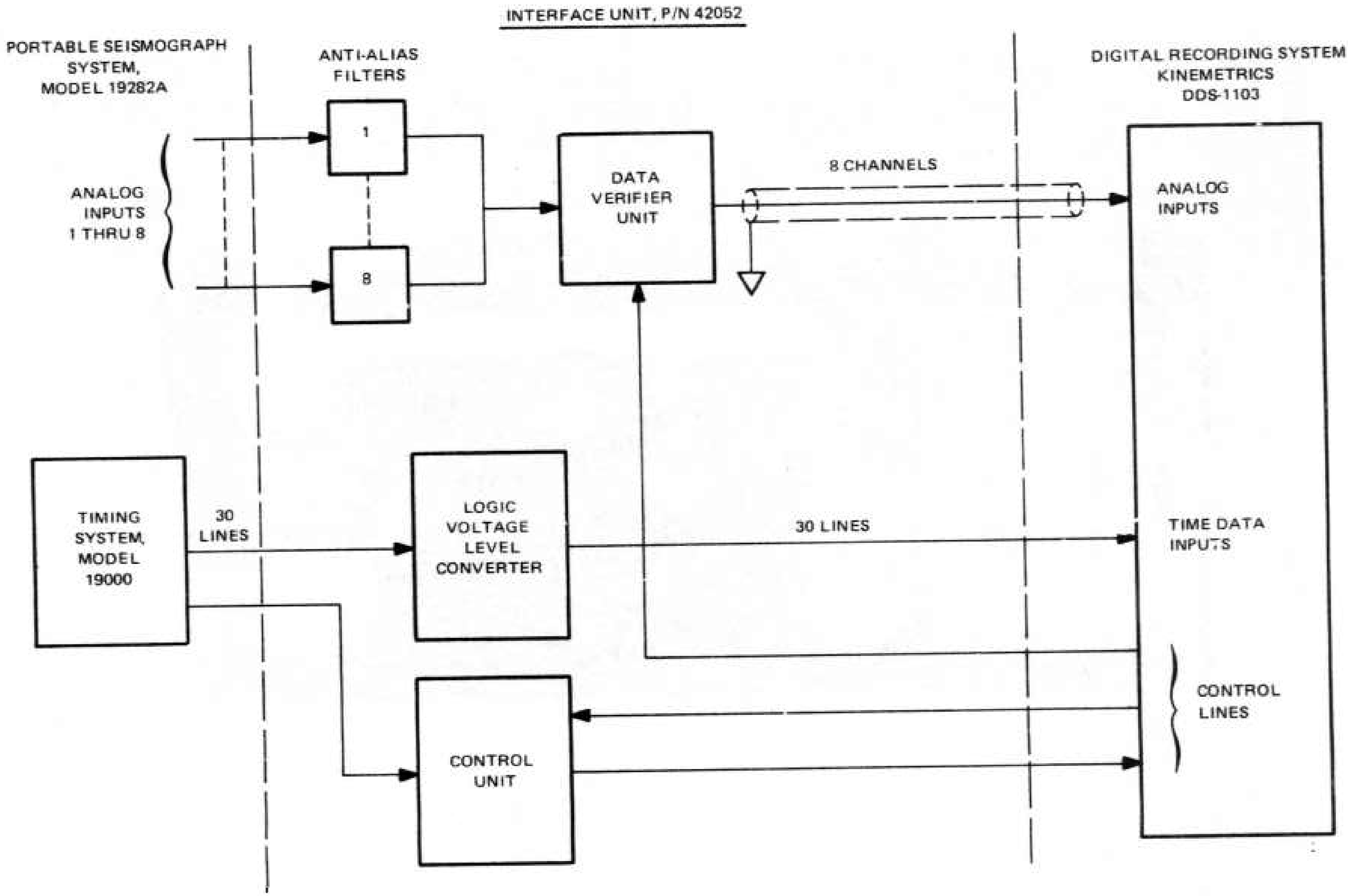

Figure 6. Block diagram of digital recording system for SDCS

G 8806

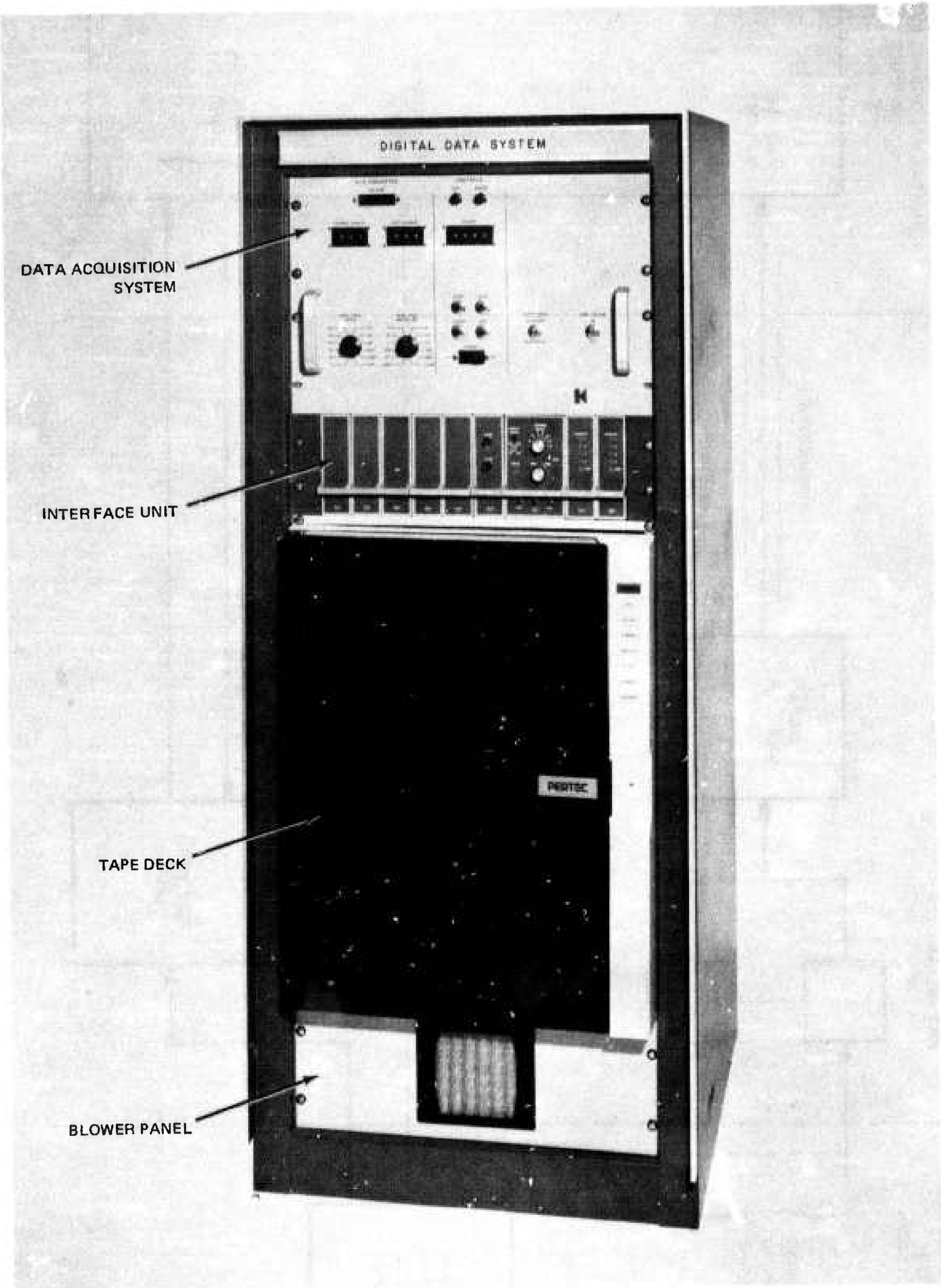

Figure 7. Digital recording system for Portable Seismograph System, Model 19282A

G 8807

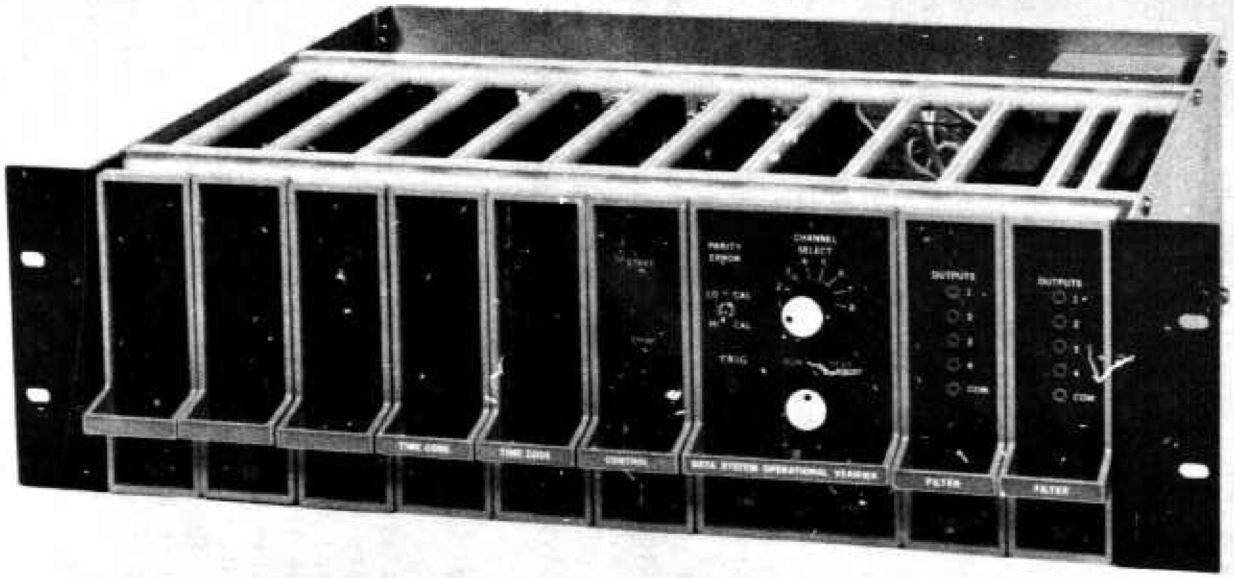

Figure 8. Interface unit, P/N 42052

G 8808

3.2.3 Data System Operational Verifier, P/N 41946

The Data System Operational Verifier, P/N 41946, is used by the station operator to determine whether or not the complete system is operating properly. In the RUN mode, seismic data are recorded on tape routinely. In the TEST mode, easily recognizable analog signals at two selectable levels are recorded on tape. These signals are then read from the tape (read-after-write) and are reconverted to analog signals in the module. By observing the reproduced data on the station oscilloscope the operator is able to check operation of the multiplexer, sample-and-hold amplifier, A-to-D converter, memories, and the relative quality of data actually recorded on tape.

3.2.3.1 Test Signal Generation

The test signal used is a series of three ramp functions generated by a 6-bit digital-to-analog converter (DAC). The DAC is reset to zero at the start of each digital record and ramp functions are generated by the scan pulse rate selected in the digital system. In this manner, ramps always start at the same level and three of them are produced for each 1008 data sample record regardless of the sampling rate selected. Each test signal consists of three 64-step ramp functions (192 counts) followed by 48 counts with the DAC held at its zero level. At count 240, the DDS-1103 memory is filled and the test signal sequence begins again. The DAC has two selectable output levels. In the first (HI CAL) mode, ramps rise from -5 to +5 volts to check system operation for the six most significant bits of the 12-bit A-to-D converter. In the second (LO CAL) mode, the output amplitude of the DAC is reduced to produce ramps rising from zero to about +160 mV to verify operation of the six least significant bits. These analog test signals are applied to each of the eight data inputs by means of a CHANNEL SELECT switch on the front panel of the Verifier. Undriven channel inputs are grounded to prevent noise pickup.

3.2.3.2 Test Signal Detection

The output of the read-after-write electronics in the tape deck is input to the Verifier. Circuitry is provided to decode each 12-bit sample (which requires two tape bytes) into two parts - the six high-bit and six low-bit portions. Each part is then input to a six-bit DAC. The analog outputs of these DAC's are available at front panel jacks. In operation, the oscilloscope is connected to HI CAL or LO CAL jacks depending on the level of the ramps being recorded. The DAC outputs remain quiescient until the memory is filled and data begins to be recorded on tape. During the approximate 125 msec interval required to write a 2048 byte record, each DAC "looks at" its portion of each of the 1008 data sample (the 32 byte header is ignored) and generates an analog representation of the digital word decoded. The oscilloscope representation consists of the three ramps made up of a series of dots for the driven channel, and a zero base line which represents the output level of the remaining seven data channels whose inputs are shorted to ground.

The entire test sequence for SP channels consists of 240 data points and is easily recognizable. For LP channels, however, each record contains only 12 data points and some experience is required to ascertain proper operation.

For a more thorough check of these channels, the DDS-1103 can be switched to the sequential mode in which all channels are sampled at the same rate. In this mode, 126 scans are required to fill the memory and two high-resolution ramps are recorded from the Verifier for each record.

3.2.4 Anti-Alias Filter, P/N 41843

One of the components necessary in most analog-to-digital processes is a filter to sharply reduce the amplitude of high frequency noise. This filter is necessary to prevent "aliases" of high frequency input signals outside the data passband from folding back into the normal data passband. For any sampling rate, "folding" of high frequency signals begins at a frequency which is one-half of the sampling rate (in Hz) and is called the Nyquist frequency. Normal practice is to include a low-pass filter for each input data line with a cut-off frequency of one-fourth the data sampling rate. In this system, the sampling rates are 20 and 1 sps for SP and LP channels respectively and the anti-alias filter corners are at 5 Hz and 0.25 Hz, respectively. The filter chosen is a six-pole (36 dB/octave) Butterworth (maximally flat) type; phase and amplitude responses for the SP and LP units are shown in figures 9 and 10 respectively. Theoretical tabular data used for these figures are reproduced in the Appendix of this report.

3.3 OPERATIONAL PROBLEMS IN THE DDS-1103 SYSTEMS

When the first two Kinemetrics systems were delivered in early September, they were immediately placed into operation in order to test the various breadboard versions of the interface unit. At this time, it was discovered that the system would not operate properly using the external scan pulses from the SDCS timer. This was the first of several problems found in the system throughout the remainder of the reporting period. In general, Kinemetrics personnel were cooperative in providing solutions, but these problems delayed considerably the fielding of the systems. In the following paragraphs, the problems are discussed. Table 2 summarizes this activity during the period from September through December.

3.3.1 Loss of Timing Synchronization

As mentioned above, the first DDS-1103 problem was discovered when the SDCS timer was interfaced with it. In this system, scan pulses (commands to sample analog data) come from the station timer in order to assure that they are synchronized with real time. It was discovered that the system would operate properly for a time, then begin to lose 50 msec (one scan) every 12-second record. A visit by a factory representative in late September verified that the problem was in the DDS-1103 rather than in the external circuitry. Subsequent testing at the factory identified the problem as a conflict between a READ function (when header data was being read into memory) and a WRITE function (when the alternate memory data were being recorded on tape). The solution required minor wiring changes which were incorporated into the two units on hand in Garland on 26 September. This modification was completed on the remaining three units before they were shipped from Kinemetrics.

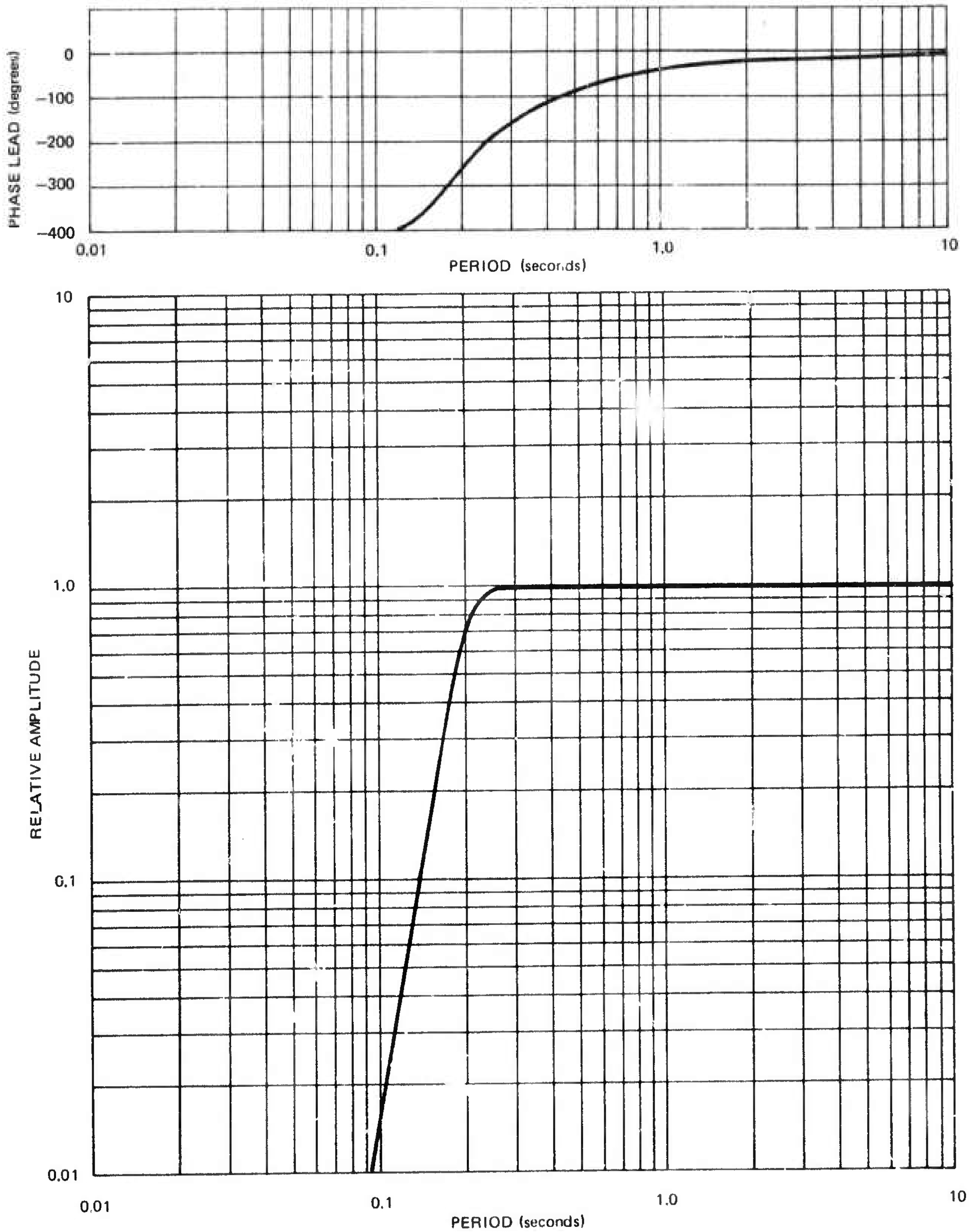

Figure 9. Theoretical amplitude and phase responses of the anti-alias filters in the short-period data channels of the SDCS digital recorders

G 8809

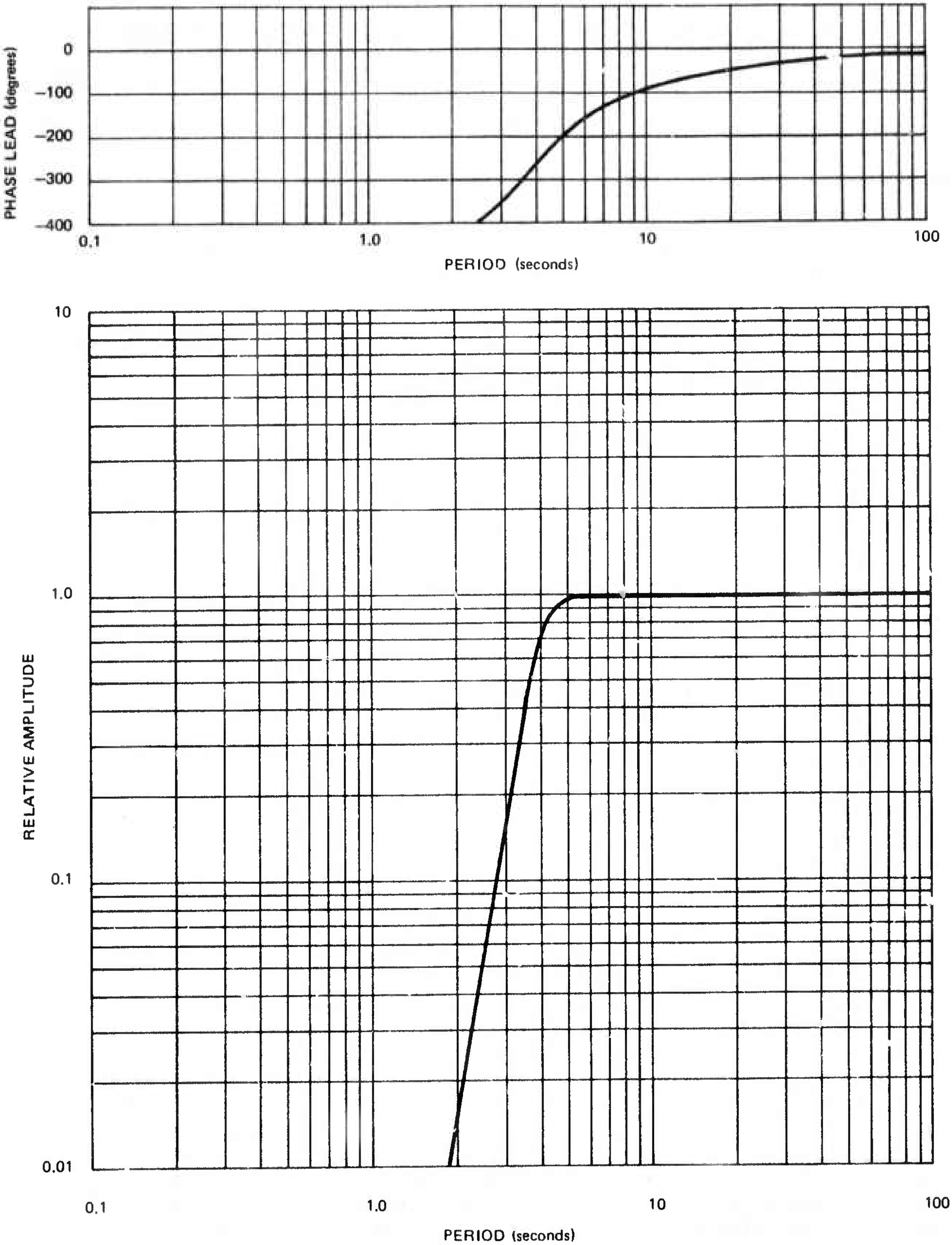

Figure 10. Theoretical amplitude and phase response of the anti-alias filters in the long-period data channels of the SDCS digital recorders

G 8810

Table 2. Summary of Operational Problems for DDS-1103 Systems

Serial Number	115	116	120	121	122
Site Assignment	WH2YK	RK-ON	CPO	HN-ME	FN-WV
Rec'd from factory	2 Sept	4 Sept	23 Oct	23 Oct	23 Oct
Mod 1 - Correct 50 msec time loss (wiring change)	26 Sept (Garland)	26 Sept (Garland)	Oct (Factory)	Oct (Factory)	Oct (Factory)
Mod 2 - Engineering change to clock circuitry for high speed operation	6 Nov (Garland)	6 Nov (Garland)	Oct (Factory)	Oct (Factory)	Oct (Factory)
Mod 3 - Memory modification (change pull-up resistors)	6 Nov (Garland)	6 Nov (Garland)	Not done	11 Dec (Houlton)	6 Nov (Garland)
Complete system returned for factory tests (extra byte)	-	29 Nov	-	-	-
Mod 4 - Correct extra tape byte problem (wiring change)	18 Dec (Whitehorse)	December (Factory)	19 Dec (CPO)	11 Dec (Houlton)	17 Dec (Franklin)
Controller drawer returned to factory for memory and A-to-D converter repair	-	-	-	-	2 Jan 76

3.3.2 Further System Modifications

While the final designs were being completed and parts ordered for the various components of the Interface Unit in Garland, Kinemetrics apparently began a study of their system in the light of the problem discovered during external interfacing. Testing on the undelivered units pointed out other design problems and modifications were developed. Meanwhile, plans were made to ship the first system, S/N 115, from Garland in late October. On 16 October, Kinemetrics requested that the first two DDS-1103 systems not be fielded in order to allow a factory representative to modify them in Garland. The first modification included installation of RC networks in the clock circuits associated with the memories. This new circuitry corrected timing problems which could cause data loss when external digital data from the SDCS timer was loaded into the header. The modification was incorporated into the last three units before shipment from the factory.

The modified units were received on 23 October and one of them, S/N 120, was thoroughly checked prior to air shipment to CPO on 31 October. Another, S/N 121, was checked and shipped via company vehicle to HN-ME on 4 November. On 6 November, the factory representative completed the modification on the first two units in Garland. At the same time, another modification was incorporated with all three units then on hand at Garland. Pull-up resistors on the memory boards were changed to lower resistance units which assured that the system would operate properly at its maximum through-put rate. Parts were supplied to modify the two units at CPO and HN-ME. The HN-ME unit, S/N 121, was modified during installation and the CPO system, S/N 120, will be modified later.

3.3.3 Elimination of Extra Tape Byte

When the first system was placed into operation at CPO in early November, recorded tapes were sent to the SDAC at Alexandria for operational and QC checks. Analysis showed that the 537th byte was being repeated at infrequent, random intervals. The problem occurred on several tapes. One of these tapes was sent to Kinemetrics where analysis confirmed the problem. A complete system, including the Interface Unit and the SDCS timer, was shipped to Kinemetrics on 21 November in order to locate and eliminate this problem. After considerable effort, the problem was found to be similar to the first problem in that there was a conflict of priority during simultaneous READ and WRITE functions. A modification consisting of several wiring changes was incorporated into the unit at the factory and several day's operation indicated no recurrence of the problem. Modification information was telephoned to system installation personnel then in the field and the required modifications were performed at CPO, FN-WV, HN-ME, and WH2YK.

3.3.4 Problems Associated with Individual Systems

During installation and first operation of the digital systems, several problems developed in individual systems which were apparently unrelated; i.e., not general design problems.

The problem with rf pickup at WH2YK was discussed in paragraph 2.4.1 above and is apparently a shielding rather than a hardware design problem.

The first tape from HN-ME showed occasional 256-count (2^8) spikes during alternate memory cycles, but was not evident on later tapes. This may have been related to the low temperatures in the building.

The FN-WV system failed during installation tests. Symptoms indicated two problems. First, the A-to-D converter was non-linear and could not be balanced to zero. Secondly, a problem was indicated in the second (or B) memory section in which no negative values could be recorded on channel number four. This second problem was definitely related to temperature as a failure could be consistently introduced if the temperature of the electronics was raised above about 85°F (29°C). The vendor was notified and the electronics drawer was returned for check and repair on 2 January 1976. The unit will be checked using components of the complete system which remains at the factory at the close of this reporting period.

3.4 FORMAT OF RECORDED DATA

The data format for the SDCS digital recorders is relatively straightforward but is complicated somewhat due to the different sample rates between SP and LP data. First the output code of the A-to-D converter is standard offset binary where

1111 1111 1111 represents full scale positive (+4.9976V),

1000 0000 0000 represents zero volts,

and 0000 0000 0000 represents full scale negative (-5.000V).

Secondly, the arrangement of data samples is as follows: Channels 1, 2, 3, and 4 sampled at 50 msec intervals for 19 scans or 76 SP samples, followed at time 950 msec after the second by samples of all eight channels. Thus, there are 84 samples for each second - 20 x 4 SP and 1 x 4 LP samples. This arrangement may be visualized as

Time	0.00	0.05	0.10	....	0.90	0.95	1.00	1.05	....
Channel	1,2,3,4	1,2,3,4	1,2,3,4	....	1,2,3,4	1,2,3,4,5,6,7,8	1,2,3,4	1,2,3,4	....

The tape format is shown in figure 11. Note that all header information is contained in the first ten tape bytes. Bytes 36 through 2048 contain 1008 data samples. Bytes 11 through 32 are zero filled so as to produce a complete record of 2048 bytes at exactly 12-second intervals. This zero filling results in some loss of recording time (about 1%) but greatly simplifies the data processing which would have been required if these bytes had been filled with data samples (split data).

RECORDED ONCE PER RECORD

9 TRACK	CHANNELS SELECTED		OP CODE	TEAM NO.		YEAR	TIME FROM EXTERNAL TIMER				22 BYTES ZERO		1ST SAMPLE		2ND SAMPLE		1008TH SAMPLE	
PARITY	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
0	1	1	1	1	1	1	200d	2d	0	0	0	0	0	2^7	0	2^7	0	2^7
1	1	1	1	1	1	1	100d	1d	40m	40s	0	0	0	2^6	0	2^6	0	2^6
2	1	1	1	1	1	1	80d	20h	20m	20s	0	0	0	2^5	0	2^5	0	2^5
3	1	1	1	1	1	1	40d	10h	10m	10s	0	0	0	2^4	0	2^4	0	2^4
4	80	8	8	80	8	8	20d	8h	8m	8s	0	0	2^{11}	2^3	2^{11}	2^3	2^{11}	2^3
5	40	4	4	40	4	4	10d	4h	4m	4s	0	0	2^{10}	2^2	2^{10}	2^2	2^{10}	2^2
6	20	2	2	20	2	2	8d	2h	2m	2s	0	0	2^9	2^1	2^9	2^1	2^9	2^1
7	10	1	1	10	1	1	4d	1h	1m	1s	0	0	2^8	2^0	2^8	2^0	2^8	2^0
	1	2	3	4	5	6	7	8	9	10	11 ...	32	33	34	35	36 ..	2047	2048

INTER RECORD GAP OR BEGINNING OF TAPE

INTER RECORD GAP

TAPE CHARACTERS (BYTES)

TAPE MOTION ←

NOTES:

1–2^0 IS THE LSB.

2– DATA FORMAT NOT PHYSICAL DATA LOCATION ON TAPE (EBCDIC CODING).

3– 2048 CHARACTERS PER RECORD.

Figure 11. Digital tape format - typical SDCS operation

G 8811

4. DATA PROCESSING

The data processing for this program has been divided into three parts; analog tape quality control performed at our Garland facility, event processing at the SDAC and the digital data processing which is also performed at the SDAC.

4.1 ANALOG TAPE QUALITY CONTROL AT GARLAND

The Quality Control procedures as performed in Garland are very important to the success of the field operations as they provide the only effective control of on-site operations. The lack of continuous visual recordings of all data channels in the field limits the knowledge that the SDCS operator can have of instrumentation problems that are developing. The playout of data from the analog records provides a ready reference for support personnel to evaluate the performance of the instrumentation. Analog record QC will continue in Garland even after the digital recording systems are fully operational for the purposes of adequate program control.

4.2 EVENT PROCESSING AT THE SDAC

The processing of data into event reports as requested by the Project Office ran behind the originally proposed schedule early in the report period. In November a reorganization of the data processing and event report preparation group was completed and the efficiency of event reporting was significantly improved.

At the end of December 1975, 75 event reports had been requested and 53 event reports had been completed. It is anticipated that this task will be back on the original schedule by the end of January 1976. Preparation of event reports from the field recorded digital records will start in early February when the last of the digital recorders is installed. The elimination of the analog-to-digital conversion of the data should be a great time saver in report preparation.

4.3 DIGITAL DATA PROCESSING AT THE SDAC

Preparations are continuing at the SDAC in Alexandria in order to begin using the digital field data as soon as systems can be considered operational. Work has consisted primarily of programming efforts for two tasks - quality control of field tape, and processing of actual data. In addition to these tasks, some programming effort was done during the initial phases of digital system operation which was necessary to better define the various operating problems which arose. Finally, the SDAC group also has the responsibility to provide recycled digital tapes for field operations.

4.3.1 Quality Control of Digital Tapes

A program (DETECT) was written to do a fully computerized quality control analysis of the digital field tapes on the PDP-15 system. Its function is to

produce a printed error detection log on the line printer for each data tape. Examples of the errors it will detect are: dead channels, clipped channels, RMS bounds analysis of equipment noise (presence of high frequency), spike detection, and timing instabilities. The program runs at only eight times real time and therefore a complete check of every 24-hour record is not practical. During normal QC operations, routine checks will be made for SP and LP calibrations, plus two thirty-minute data segments to determine both day and nighttime operating characteristics. It may be possible to make this program run faster in order to more fully check each tape, as more experience is gained during routine data use.

When the CPO "extra byte" problem was discovered, a program called TEST was written to read tapes and determine whether each record contained 2048 tape bytes. This program will continue to be used as necessary.

4.3.2 Data Processing from Field Digital Tapes

Considerable programming effort is continuing under the SDAC contract to prepare for the change from analog-to-digital recording in the field. Processing is to be done on the PDP-15 system. A program is being finalized for viewing of the SDCS data on the graphics terminal. The program will also include capabilities to scale the data as necessary and to calibrate it. This will allow generation of calibrated SUBSET tapes which can then be used with existing programs to generate the required event reports. It is expected that this and other programs necessary to use digital data will be completed by the time that all field systems are considered completely operational.

5. SPECIAL PROJECTS

During this reporting period, two programs related to operation of the Model 36000 Borehole Seismometer System were proposed as requested by the Project Office. A program to investigate the effects of depths to 3000m on LP and SP seismic signals was indefinitely postponed. A program to study the effects of convections in boreholes was approved. A test plan was then written outlining the program to first, determine the cause or causes of extraneous LP noise, and second, to develop hardware or techniques to eliminate or minimize the effects of this phenomena.

Work under this task will begain as soon as the borehole facility in Garland is available. It is expected that work can begin by early March 1976.

APPENDIX

THEORETICAL AMPLITUDE AND PHASE RESPONSE DATA

TOTAL SYSTEM RESPONSES

VELOCITY TRANSDUCER - GALVO COMBINATION COUPLED CALCULATED
6 DB LOW CUT FILTER AT .010 HZ
12 DB HIGH CUT FILTER AT 10.000 HZ WITH .7070 DAMPING
12 DB HIGH CUT FILTER AT 2.050 HZ WITH .3850 DAMPING

FREQ	PER	AMPT	ANGT
.1000	10.0000	.0012	263.6
.1500	6.6667	.0041	255.5
.2000	5.0000	.0098	248.2
.2500	4.0000	.0195	241.0
.3000	3.3333	.0343	233.8
.4000	2.5000	.0846	218.7
.5000	2.0000	.1708	202.1
.6000	1.6667	.2995	184.0
.8000	1.2500	.6511	145.1
1.0000	1.0000	1.0000	109.8
1.5000	.6667	1.6762	46.9
2.0000	.5000	2.2845	-3.4
2.5000	.4000	2.6359	-54.2
3.0000	.3333	2.3921	-104.1
4.0000	.2500	1.2172	-177.2
5.0000	.2000	.5860	-219.8
6.0000	.1667	.3118	-248.7
8.0000	.1250	.1100	-289.3
10.0000	.1000	.0546	-318.5

Amplitude and phase response data for SP seismographs at CPO,
14 March through 31 December 1975

TOTAL SYSTEM RESPONSES

NO TRANSDUCER - FILTER RESPONSES ONLY
12 DB HIGH CUT FILTER AT 5.000 HZ WITH .7070 DAMPING
12 DB HIGH CUT FILTER AT 5.000 HZ WITH .9640 DAMPING
12 DB HIGH CUT FILTER AT 5.000 HZ WITH .2590 DAMPING

FREQ	PER	AMPT	ANGT
.1000	10.0000	.9997	-4.4
.1500	6.6667	.9997	-6.6
.2000	5.0000	.9997	-8.8
.2500	4.0000	.9997	-11.1
.3000	3.3333	.9997	-13.3
.4000	2.5000	.9998	-17.7
.5000	2.0000	.9998	-22.1
.6000	1.6687	.9998	-26.6
.3000	1.2500	.9999	-35.5
1.0000	1.0000	1.0000	-44.5
1.5000	.6667	1.0003	-67.1
2.0000	.5000	1.0006	-90.4
2.5000	.4000	1.0008	-114.5
3.0000	.3333	1.0001	-159.9
4.0000	.2500	.9656	-198.2
5.0000	.2000	.7079	-270.0
6.0000	.1667	.3180	-330.6
8.0000	.1250	.0596	-393.4
10.0000	.1000	.0156	-425.5

Theoretical amplitude and phase response data for the short-period anti-alias filters in the digital recording system for SDCS

TOTAL SYSTEM RESPONSES

NO TRANSDUCER - FILTER RESPONSES ONLY
12 DB HIGH CUT FILTER AT .250 HZ WITH .7070 DAMPING
12 DB HIGH CUT FILTER AT .250 HZ WITH .9640 DAMPING
12 DB HIGH CUT FILTER AT .250 HZ WITH .2590 DAMPING

FREQ	PER	AMPT	ANGT
.0100	100.0000	.9998	-8.8
.0125	80.0000	.9998	-11.1
.0167	59.9880	.9998	14.8
.0200	50.0000	.9999	-17.7
.0250	40.0000	.9999	-22.1
.0333	30.0030	.9999	-29.6
.0400	25.0000	1.0000	-35.5
.0500	20.0000	1.0001	-44.5
.0571	17.5009	1.0002	-50.9
.0667	14.9993	1.0003	-59.5
.0800	12.5000	1.0005	-71.7
.1000	10.0000	1.0007	-90.4
.1250	8.0000	1.0009	-114.5
.1667	5.9999	.9976	-158.0
.2000	5.0000	.9687	-198.2
.2500	4.0000	.7080	-357.6
.4000	2.5000	.0596	-393.4
.5000	2.0000	.0156	-425.5
.5714	1.7500	.0070	-440.7
.6667	1.5000	.0028	-455.5
.8000	1.2500	.0009	-470.0

Theoretical amplitude and phase response data for the long-period anti-alias filters in the digital recording system for SDCS